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### LASER PROPULSION TECHNOLOGICAL DEMONSTRATOR ROCKET MODE WITH ABLATIVE SYSTEM

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**Abstract.** *The aerospace research conducted on the Prof Henry T. Nagamatsu Laboratory of Aerothermodynamics and Hypersonic at the Institute for Advanced Studies (IEAv) is developing a new propulsion system, based on the laser propulsion. The Laser Propulsion Technological Demonstrator (DVPL) follows the lightcraft concept, with an axisymmetric geometry, where its leading-edge acts as a compression system, which directs the air flow to the ionization region. The Vehicle's trailing edge has dual utility, acting as a reflecting mirror to focus the laser beam and as an expansion surface (nozzle) to accelerate the hot gases produced by the breakdown of the air through the laser radiation or by the laser ablation of onboard ablative material. When DVPL reaches the rocket mode, the inlet is closed and an ablative material is irradiated by the laser beam on the ionization region. Laser ablation is the removal of material from a substrate by direct absorption of energy from the laser. The acceleration of the gases produced by the laser ablation process during the flight over rarefied atmosphere regions and for deep space. This work presents the methodology to select a material to be used for laser ablation during the rocket mode, based on the polymer class due the attractive mechanical properties and economical aspects.*

**Keywords:** *Lightcraft, Laser propulsion, Laser ablation, Polymers*

## 1. INTRODUCTION

The man has been making great strides in aerospace technology with the space race during the period of the Cold War where the Union of Soviet Socialist Republics, launched on October 4, 1957, the Sputnik I, the first satellite into space, launched by chemical propulsion (rocket engine).

Later, the United States of America launched the Apollo 11 on July 20 of 1969, using rocket engines to put the humans for the first time on the moon.

Currently the aerospace industry has achieved great technological development, but the most used form of propulsion to space access is still the chemical rocket engines.

The new propulsion systems in development seeks to reduce costs and increase the safety of the launching, because the rocket engines (chemical propulsion) allows only 3% of its weight for payload, what results in a cost of US\$ 20,000.00 per kilogram of transported material. On the rocket engine 86% of the weight corresponds to the fuel, 6% is the structure and 5% is the engine.

The Prof. Henry T. Nagamatsu Aerothermodynamics and Hypersonic Laboratory develops studies on supersonic combustion and laser propulsion using numerical analysis (CFD), pulsed lasers of high power, hypersonic shock tunnel that can reproduce speeds around Mach number 6 to 25, stagnation enthalpy of approximately 10 MJ / kg and 16 MPa of pressure. These methodologies support the development of the Brazilian Aerospace Hypersonic Vehicle 14-X [1]. DVPL (Fig. 1) is the model on a micro scale for future application analysis and is used to obtain results with greater accuracy being economically viable and this work will be used to study materials to be used in the ablation system.



Figure 1. Lightcraft [2].



Figure 2. Night flight test, with expanding luminous air-plasma exhaust [2].

Table 1. Polymers Selection [3]

Material	Specific weight [g / cm <sup>3</sup> ]	Specific heat [J / K]	Melting point [°C]	Dielectric strength [kV / mm]	Dielectric loss factor at 10 Hz
Nylon	1.14	1.7	220 245	30 (80) 36 (100)	0.03 (0.3) 0.025 (0.2)
Polyethylene	0.95	1.7	130	110	0,0002
Polytetrafluorethylene (Teflon)	2.14/2.2	0.970	+327	20/80	0.3 to 0.7 10 <sup>-4</sup>
PVC	1.16 / 1.35 1.30/ 1.58	0.3/0.5 0.25/0.35	127 150	300 / 400 350/500	-- --
Polypropylene	0.91	1.7	165	100	0.0002
Polyacetal	1.41	1.5	165	50 50	0.03
Acrylic	1.17/1.20	0.35	160	450/550	--

## 2. METHODOLOGY

The principles of laser ablation allow the correct understanding of the laser-matter interaction, allowing the selection of the material to use in the rocket mode of the DVPL. Consequently, the design of the ablative system should be conducted, considering that the energy of the laser radiation is absorbed by a propellant followed by the supersonic ejection of a beam of highly ionized matter. Theoretical studies should be conducted to understand the phenomena of ablation and physical principles of laser operation, and numerical analysis should be developed to design the ablation system. Using previous studies Sinko and Gregory and obtain formulas for analysis of the effects of laser ablation data and analyze its chemical propulsion.

## 3. RESULTS

The results obtained through this work will allow future works include performing numerical flow simulations besides knowing the best materials to experiments on laser laser propulsion considering the ablation system for the DVPL rocket mode. The results for numerical simulation show a high value of Isp and efficiency in the absorption of laser energy.

Table 3 specific impulse

Material	$\Phi T$	$\Phi\alpha$ J=cm <sup>2</sup>	P g=cm <sup>3</sup>
Polyethylene	0,9	6,14	0,95
Polypropylene	0,09	9,6	1,31
Polyacetal	0,071	1,32	1,43
Polytetrafluorethylene (Teflon)	0,23	8,3	2,15
PVC	0,21	5,2	1,37

The importance for the comparison with the chemical propulsion is analysis of the  $\Phi T$  transmissivity of material surface and  $\Phi\alpha$  ablation threshold based on fluence directed at target, checking the withdrawal and absorption at the point reached by the radiation and compare the material.

Table 3 Polymers ablation threshold fluence

Material	Polyethylene	Polyacetal	Polytetrafluorethylene
F $\alpha$ J=cm <sup>2</sup>	0.021	0.0223	0.0141

## 4. CONCLUSION

It is obtained that the ablative system of the rocket mode of Lightcraft, use as a propeller polymers material with the cost inferior, and becomes the launch of Lightcraft, would be suitable for nanosatellite launches with weigh between 10 and 100 kg. The material class of polymers is the best solution, to be applied as propellant for the DVPL rocket mode, due the low cost. Simulate numerical demonstrates compliance with experimental analyzes thus using this methodology for the application of experimental analysis reducing the number of tests and making more effective.

It allows Brazil to develop high added value technologies and to accomplish the satellite launching mission, where the DVPL should carry micro and nanosatellites.

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